U.S. Fish & Wildlife Service

Abernathy Fish Technology Center Newsletter

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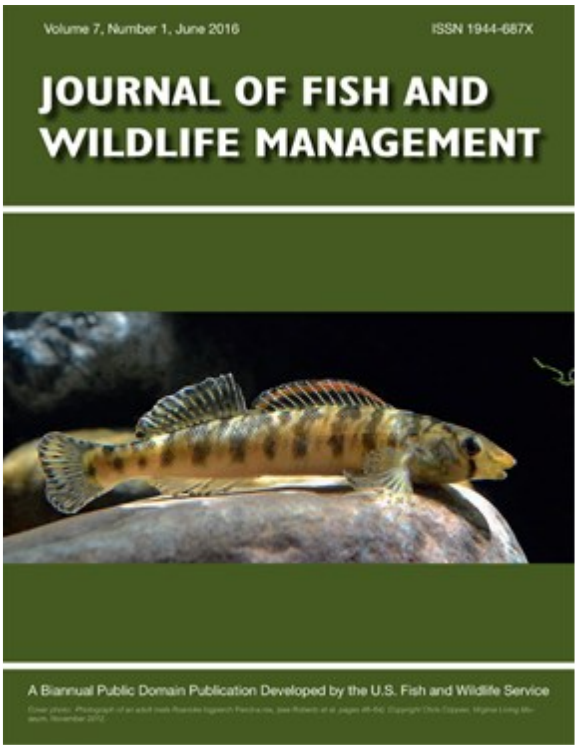
In this issue:

Serving the Pacific and Pacific Southwest Regions

Peer Reviewed Publications



A set of standards have been developed for FTCs over the years. All FTCs are responsible for publishing at least one peer reviewed paper per year, and most FTCs produce many more. The requirement is so negligible because publishing papers is more a means than an end for FTCs. Our primary function is to provide information that may be used to make scientifically based management decisions. Sometimes that information is very important but not unique or complete enough to publish. Examples include results from proximate analyses of NFH fish feed samples used to help to ensure feed quality and from rapid response genetic analyses to help with decisions about transporting bull trout above dams. Sometimes the information is so important, that it is almost obligatory to share it via a peer reviewed paper. A list of the 13 papers and one book chapter that Abernathy FTC staff published in 2016 may be found on the last page of this newsletter. Enjoy!

Program Highlights

Administration/Facilities

Winter storms wreaked havoc with trees at AFTC. Jeff, Jim and Steve M. removed downed trees from the access road to the settling basin, and Jeff also removed a "sweeper" that was accumulating debris and a concern for neighbors downstream.

Steve M. updated the safety plans, continued inspection of Well 4 and worked with contractors to resolve the backflow preventer issues.

Patty worked on NFH assessments with the assessment planning team.

Doug and Patty met with representatives from BPA to discuss their new contract tracking and reporting software (Gemini) that will eventually replace Pisces desktop.

Several AFTC staff including SCA Interns Margot and Paul visited the Portland Zoo. They received a tour of

Crowding steelhead in the raceway to capture them for tagging. Pictured (Left to Right) are: Paul, Kelli, and Margot. Photo Credit: Doug Peterson

Staff

Administration & Facilities

Patty Crandell, Director
Steve Dyer, Administrative Officer
Alina Nestjorkina, Administrative Assistant
Mark Hack, IT Specialist
Jeff Poole, Water Treatment Plant Operator
Jim Lowell, Maintenance Worker
Steve Money, Facility Operations Specialist

Conservation Genetics

Christian Smith, Regional Geneticist
Justin Bohling, Conservation Geneticist
Matt Smith, Conservation Geneticist
Jennifer Von Bargen, Lab Geneticist
Brice Adams, Conservation Geneticist
Matt Piteo, Biological Science Technician
Ben Prom, Biological Science Technician

Physiology & Nutrition

Ann Gannam, Regional Nutritionist
Richard Glenn, Microbiologist
John Holmes, Fish Biologist
Ron Twibell, Acting Regional Physiologist
James Barron, Fish Biologist
Kelli Hawke, Biological Science Technician
Rachel Headley, SCA Intern

Quantitative Ecology & Technology

Doug Peterson, Senior Scientist
Ben Kennedy, Fish Ecologist
Will Simpson, Fish Ecologist
Kurt Steinke, Electronics Engineer
Margot Cumming, SCA Intern
Paul Kieras, SCA Intern

Program Highlights— continued

the Zoo's Education Center and an explanation about the conservation partnership between the Zoo and the FWS.

Patty took part in the Leadership Conversation on Welcoming Workplaces with Robyn Thorson, Terry Rabot, and other regional project leaders.

Justin delivered safety training on proper use of fire extinguishers for the AFTC staff.

Tagging crew for hatchery steelhead. Left to Right: Ben, Kelli, Margot, Paul, Richard. Phot Credit: Doug Peterson

Patty was asked by Joell Bader, FTC Coordinator (FAC) to provide information about peer reviewed publications. Abernathy FTC was involved with 13 publications and one book chapter last year.

Brice and James announced the FAC's Hatchery Management Training to be held in May

Conservation Genetics

Matt P. became the newest member of the Conservation Genetics Program in January. Matt completed his M.S. degree at The University of Alabama, Tuscaloosa, and brings to Abernathy FTC several years' worth of experience conducting research on population genetics and life histories of fishes. Welcome, Matt!

Jennifer and Justin worked on implementation of Genotyping in the Thousands (GTSeq) at Abernathy. GTSeq is a new analysis protocol developed by our partners at Columbia River Inter-Tribal Fish Commission (CRITFC), which has vastly improved the efficiency and speed with which large-scale genetic analyses (those involving thousands of individuals) can be conducted. DNA libraries for redband and steelhead trout were built and then sent to the CRITFC laboratory to be loaded on their Next-Gen DNA sequencing instrument. The data from this initial run will be used to evaluate population structure in redband trout in the upper Deschutes Basin. Further development of this protocol is currently underway in collaboration with Washington Department of Fish and Wildlife (WDFW), Illumina Inc., and our LaCrosse Fish Health Center.

Ben P. extracted DNA, and genotyped, Hoko River coho salmon samples. The Hoko River is near Makah NFH, and our partners at the Northwest Indian Fisheries Commission collected samples from the coho there last year in hopes of finding out how similar they are to the stock at our hatchery. Data from these fish will be incorporated into the next round of NFH broodstock genetic profiles.

Justin analyzed genetic data for bull trout in the Upper Willamette River as part of a collaborative project with the Army Corps of Engineers. The results of this project were presented to our partners at an interagency

Program Highlights— continued

meeting in Springfield, OR, and were shared more broadly with partners via a final report.

Jennifer and Christian worked with Red Bluff FWCO staff to address several genetic information needs for propagation of endangered Winter Run Chinook salmon and Livingston Stone NFH. Needs included a review of the proposal for broodstock collection submitted by the FWS to the State of California, guidance on protocols for avoiding inbreeding in the captive broodstock program, and interpretation of carcass survey data on fitness impacts of our program on the naturally-spawning fish.

Matt S. drafted a study plan for analysis of juvenile redband trout steelhead captured above Pelton Dam on the Deschutes River. The study plan was requested by Portland General Electric, who asked for assistance in determining whether the fish are descended from the native stocks or from hatchery fish planted above the Dam.

Jennifer worked with the Mid-Columbia River FWCO and WDFW to draft a study plan for a rapid response program for bull trout captured below Clear Creek Dam (Yakima Basin). Previous work by the FWS has indicated that the fish ladders on the dam may be insufficient to allow bull trout to pass, so information on fish origins would be useful for facilitating manual passage. The group is hoping to start using genetic data to inform passage decisions later this year.

Nutrition

Nine feed samples were received from the hatcheries in January and February. As part of the routine analyses, feeds from the hatcheries were checked for rancidity. Ann wrote the feed memos which were sent to the hatchery and the feed mill. A rancidity issue is being investigated.

Coordinated work has begun with Kari Dammerman at the Columbia River FWCO on her altered feeding regime trial starting at the Columbia River Gorge NFH Complex. We will be taking whole fish bodies for proximate analysis during the study and physiological samples will be taken prior to release.

Tim Whitesel of the Columbia River FWCO and Ann completed a survey of Pacific region employees for the FAC Training and Employee Development Work Group to gain information about employee training needs. The work group is chaired by Matthew Patterson at NCTC.

Richard traveled to Hagerman NFH to collect samples for

Reports and Publications

Bohling, J. H. 2017. Assessment of bull trout genetic diversity, population connectivity, and genetic introgression in the Upper Willamette Basin, OR. AFTC Final Report.

Peterson, D. P., W. S. Simpson, and L. Beck. 2017. Progress Report - Common Carp Biomass Threshold Experiment Pilot Study Work Conducted in Fall 2016. AFTC Interim Report. 9 pp.

Roberts, J. J., K. D. Fausch, M. B. Hooten, and D. P. Peterson. 2017. Nonnative trout invasions combined with climate change threaten persistence of isolated Cutthroat Trout populations in the southern Rocky Mountains. North American Journal of Fisheries Management 37(2):314-325.

Von Bargen, J., and C. T. Smith. 2017. Genetic Identification of Endangered Winter-Run Chinook Salmon in the Sacramento River, CA. AFTC Final Report.

Program Highlights - continued

ATPase analysis. This is the beginning of a five month sampling that will occur in an attempt to see why the steelhead from the Partial Recirculating Aquaculture System (PRAS) system may not be moving downstream. Fish were also collected from both, PRAS and raceway systems for whole body proximate composition.

James, Ann, Richard and Kelli collected the final samples for the lamprey sediment grain size and frequency of tank cleaning studies. These two studies concentrated on various details that will be used to develop a rearing standard operating procedures. James presented preliminary data when he and Ann met with Mary Moser, NOAA, and Ralph Lampman, Yakama Nation (cooperators in the Chelan PUD lamprey project). James completed the new statement of work for the next year of the lamprey project.

Racheal (SCA intern) with help form Kelli, is nearing completion of the lab analysis of the coho salmon eggs collected at Quilcene and Eagle Creek NFHs. The objective of the project is to examine the relationship between egg nutrient composition and reproductive success and to determine whether egg composition may be influenced by ocean conditions. The information may help improve understanding of how changes in ocean conditions may affect future NFH production. Rachel and Kelli are also analyzing proximate composition of the monthly Bonneville Power Administration (BPA) steelhead samples. The objective of the BPA work is to alter hatchery feed composition to produce hatchery fish with lipid levels more similar to those of wild fish. Ron and Kyle Hanson from Columbia River FWCO, collected gill samples at Lyons Ferry (Washington Dept. of Fish and Wildlife) and Irrigon (Oregon Dept. of Fish and Wildlife) fish hatcheries as part of a project evaluating the effects of rearing conditions on steelhead smolting.

Kelli Hawke and Rachel analyzing for protein. Photo Credit: Ann Gannam

Only two Abernathy hatchery steelhead have returned so far in 2017, along with two out of basin strays.

Quantitative Ecology & Technology (QET)

Will, Doug, Kurt, Paul, and Margot worked on the design of a Passive Integrated Transponder (PIT) array for a fish pump system at Hagerman NFH. The PIT system will enumerate tagged steelhead and allow analysis of tag loss in fish reared in a PRAS system vs. those reared in traditional raceways

Approximately 1,500 steelhead from the BPA project were PIT tagged by the Physiology and Nutrition Program. The fish will be released into Abernathy Creek during April-May and PIT arrays will provide data on outmigration timing, and whether there are any differences between fish of hatchery vs. wild parents and between fish fed a low vs. high fat diet.

Program Highlights— continued

Doug submitted Abernathy FTC's updated Hatchery Genetic Management Plant (HGMP) to NOAA Fisheries for review. BPA requires Abernathy FTC to have a current HGMP under the terms of its contract for the steelhead reproductive success project.

Kelli and John working in the raceways in the snow. Photo Credit: Ron Twibell

Paul and Margot worked in Conservation Genetics genotyping juvenile steelhead samples from Abernathy Creek that will be used to examine life history differences of juvenile steelhead produced by hatchery origin vs. natural origin adult steelhead spawning naturally.

Outreach

AFTC was the focus of a Tumblr outreach write up: http://usfwspacific.tumblr.com/post/155404404530/intern-adventures-wading-into-electrofishing-on

Brad Halverson, member of the Advisory Board, Oregon Hatchery Research Center, Member of Association Northwest Steelheaders and Coastal Conservation Association, and Kyle Smith member of the Advisory Board and of Trout Unlimited took a tour of AFTC.

Will assisted staff at Dworshak NFH with troubleshooting the NFH's PIT system that interrogates fish as they exit the NFH.

SCA interns Margot and Paul met with Jeff Johnson from the Columbia River FWCO to discuss how they can help with outreach projects. They anticipate helping him do a variety of activities including: going into public schools in Portland and doing dissections, teaching kids about salmon life history and another activity on adaptions to living in aquatic/marine environments. Margot and Paul also met with Cheri Anderson at Spring Creek NFH to discuss how they could participate in the NFH's Salmon in the Classroom program. They anticipate visiting the NFH again when school children are visiting the hatchery to participate in this program.

Kelli got the supplies and equipment to set up an aquarium to be used for the outreach event, Salmon in the Classroom, at the Wahkiakum Middle School. James and Racheal helped her set up the tank to be sure everything was running properly. She will move eyed eggs there mid-March.

Meetings, Conferences and Trainings

Ben and Justin attended the annual meeting of the Oregon Chapter of the American Fisheries Society, and presented a paper titled “Juvenile migration behavior of hatchery reared steelhead from an integrated brood-stock fed a standard lipid vs low lipid diet”.

Justin’s presentation, "Applying genomics to bull trout: biological insights and management applications" described the development of range-wide genetic monitoring tools by Abernathy FTC, WDFW, and CRITFC.

Patty took part in Pacific Region FAC’s Project Leader, Westside manager, and FTC calls. The FTC calls concentrated on scheduling the annual FTC meeting. It will be held July 10-14 at NCTC.

Steve participated in Contracting Officer Representative (COR) refresher training and Steve participated in supervisory training. Alina completed all of her FBMS training.

Patty took part in a North Pacific Landscape Conservation Cooperative (NPLCC) Science/TEK Subcommittee meeting to help define NPLCC Landscape Conservation Goals and develop objectives/actions for the goals. In a follow up meeting the S-TEK Terrestrial Connectivity workgroup provided more information for Terrestrial Connectivity.

Patty participated in ESA section 7 training in the Regional Office.

Will and Doug conferenced with the Bureau of Reclamation and Confederated Tribes of the Umatilla Indian Reservation (CTUIR) to discuss plans for an antenna system in the Umatilla River that will detect juvenile Pacific lamprey. Will started drafting the statement of work for FY17.

Doug and Patty met with representatives from BPA to discuss their new web-based contract tracking and reporting software (Gemini) that will eventually replace Pisces desktop application.

Christian and Matt S. participated in multiple FWS Conservation Genetics Community of Practice teleconferences. The meetings were focused on addressing projects funded by HQ this year, including the development of Genetic and Propagation Plans for Native Aquatic Species.

Several geneticists attended an online webinar of The Conservation Genetics Workshop. The Workshop was hosted by the Pacific Islands FWO, U.S. Geological Survey (USGS), and the University of Hawai‘i at Mānoa, and the objective was to provide information on genetics capabilities and costs to natural resource managers, and to solicit questions/issues from those managers which genetic tools might help address.

Brice attended the Lewis River Bull Trout Consultation Meeting at the local WDFW office. Brice presented results of genetic monitoring that Abernathy FTC and PacifiCorp are conducting to facilitate bull trout passage above mainstem dams on the Lewis River.

Christian participated in the Deschutes Basin Spring Chinook Production Coordination Meeting. This annual interagency meeting provides an opportunity to share information on production and issues impacting hatchery fish with our partners. Christian presented the results of a study conducted by Columbia River FWCO and Abernathy FTC to evaluate the genetic origins of Parkdale Hatchery fish.

Justin and Brice attended the Global Biodiversity Genomics Conference. Justin’s presentation, "Old school vs. new school: Comparing inferences of population structure using RADseq and microsatellite datasets", described some of the newest tools available to conservation geneticists. Brice’s presentation, "Don’t Cross the Streams: Population Structure Among Three Adjacent Steelhead Streams", described the results of ongoing

work with WDFW and BPA to examine the impacts of hatchery fish on wild populations.

Jennifer and Christian represented the FWS in the Genetics Project Work Team. This biannual coordination meeting is part of the State of California's Interagency Ecological Program, and aims to coordinate work and promote sharing by multiple agencies and other stakeholders in the State.

Matt S. had several meetings with researchers from USGS and the University of California at Davis to discuss final preparations for a BOR-funded study of the genetic information needs for conservation and management of endangered Klamath Basin suckers.

Christian participated in a teleconference for the USGS Bioinformatics Community of Practice. The Community has monthly meetings to share information about resources for using computer clusters to analyze genetic data.

Richard is on the Workplace Quality Team and participated in a review of the Federal Employee Workplace Survey that was done in 2016 to propose ideas to improve federal employee job satisfaction.

Ron attended the co-managers' meeting for Quilcene NFH and presented preliminary data concerning the analysis of coho eggs collected at Quilcene NFH. The project objective is to obtain baseline information on coho salmon egg biochemical composition and determine whether such data can be used to predict hatching success and survival of progeny.

Ann attended the COR refresher training.

Ann and Tim Whitesel from the Columbia River FWCO met with the FAC training workgroup.

James, Ann and Ron, working with Sonia Mumford and Sharon Lutz, both from the Olympia Fish Health Center, conducted the Nutrition/Fish Health workshop for the Makah and Quinault NFHs as well as Makah tribal members. The picture shows the "perfect" end to a workshop day, it was a dark and stormy night outside of Forks, WA. The tree blocked Hwy 101.

Ron, James and Ann attended the Aquaculture America meeting. Ron spoke on the effects of dietary lipid source and ultraviolet radiation on growth and fatty acid profile of steelhead; James spoke on the evaluation of effluent waste water from salmonid culture as a potential food and water supply for culturing larval Pacific lamprey; Ann spoke on evaluation of the effects of an alternative feeding regime applied in the hatchery on growth and body composition of juvenile Chinook salmon. James' paper has been nominated as one of the top papers in his session at the meeting.

Tree fallen over the road on the return trip from Neah Bay. Photo Credit: Ann Gannam.

Ongoing Projects

Water Velocity Effects on Salmon as Reared in Recirculating Systems. *Management Need:* Determine the effects of water velocity on composition, growth, condition, and performance of juvenile PNW salmon as applied to recirculating systems in support of hatcheries in the Pacific Region considering the use of recirculating systems. *Partners:* Pacific Region National Fish Hatcheries, Fishery Resources Program via Fisheries Operations and Need System (FONS).

Diet development for Lost River and short nose suckers in the Klamath River Basin. *Management Need*: Determine dietary needs of listed populations to assist in recovery. *Partners*: Klamath Tribes, Klamath Falls FWO, California/Nevada FHC.

Development of diets and rearing techniques for the culture of Pacific lamprey, *Entosphenus tridentatus*. *Management Need*: Assist Tribal partners in developing methods for the artificial propagation of Pacific lamprey, a species of concern. *Partners*: Yakama Nation; Fishery Resources Program via FONS.

The physiological response of white sturgeon to handling stress in captivity. *Management Need*: Determine if the stress from catch and release angling is detrimental to survival of white sturgeon, a species of concern. *Partners*: Dalhousie University; Carleton University.

Pacific Region's Fish Feed Quality Control (FFQC) Program. *Management Need*: The FFQC Program, the only one of its kind in the FWS, provides quarterly monitoring of the quality of the commercially produced fish feeds used at Pacific and Pacific Southwest Regions' NFHs. Information is compiled on an annual basis and used in the development of the Pacific Region fish feed contract. *Partners:* Pacific and Pacific Southwest Region's NFHs, Oregon, Washington, Idaho, and Tribal fish hatcheries.

Effects of dietary lipid source and ultraviolet radiation on sunburn and steatitis in Steelhead, *Oncorhynchus mykiss*. *Management Need:* Provide information regarding the potential relationship between fish nutrition and sunburn in steelhead. *Partners*: Pacific Region National Fish Hatcheries

Evaluation of thermal exposure of adult Chinook salmon during the migration to Warm Springs National Fish Hatchery. *Management Need:* Determine if Chinook salmon migrating to Warm Springs National Fish Hatchery experience thermal stress. *Partners*: Warm Springs National Fish Hatchery, Lower Columbia Fish Health Center, Confederated Tribes of Warm Springs.

Natural reproductive success and demographic effects of hatchery-origin steelhead in Abernathy Creek, WA. *Management Need*: Provide information to help managers minimize differences between NOR and HOR fish. *Partners*: Bonneville Power Administration; Washington Department of Fish and Wildlife.

Climate change vulnerability assessments of Pacific Region National Fish Hatcheries. *Management Need:* An understanding of the anticipated habitat changes under different climate change scenarios provides managers with information to proactively respond to these conditions and their impact on NFHs. *Partners*: Pacific Region NFHs; Mid-Columbia River FRO; Fishery Resources Program via FONS.

Fish Suppression of common carp in Malheur Lake using electrofishing to target eggs and embryos. *Management Need*: Determine the feasibility of using electrofishing to kill eggs and embryos for control of invasive common carp in Malheur Lake. *Partner:* Malheur NWR.

Antenna design for the Biomark IS1001 PIT tag reader. *Management Need*: Provide expert level engineering and technical assistance to partners monitoring species of interest using new technologies while reducing biologist time spent in design and troubleshooting. *Partners*: NOAA Fisheries, USFWS Green Bay.

Entrainment and bypass of ESA-listed salmon at irrigation diversions on the Umatilla River. *Management need*: Determine what environmental factors influence the magnitude of fish entrainment into irrigation canals and if captured fish are successfully screened and returned to the Umatilla River using PIT tag technology. *Partner*: Bureau of Reclamation

Aquatic organism passage (AOP) at remediated stream road crossings. *Management Need:* Assess the efficacy of genetic, direct capture, and remote sensing methods to verify fish passage through remediated culverts. *Partners*: US Forest Service, Trout Unlimited.

Mekong River fish ecology and sustainable development. *Management Need*: Assess the scientific capacity and data needs for resource managers in Laos and Cambodia to address hydroelectric development on the main stem Mekong River. *Partners:* USGS, US DOI International Technical Assistance Program (ITAP)

Effectiveness of transitioning to a locally-sourced steelhead broodstock at Winthrop National Fish Hatchery. *Management Need*: Determine if hatchery improvement programs and actions are achieving the expected biological performance objectives. *Partners:* USFWS Mid-Columbia WW and NOAA Fisheries.

Stress response of juvenile steelhead salmon to electrofishing and tagging under different thermal regimes. *Management need:* To understand how fish respond to capture and handling under conditions experienced in late summer. *Partners:* USFWS Directorate Fellows Program.

Ongoing Projects—continued

Evaluation of the spatial and temporal distribution of juvenile Chinook Salmon in the Entiat River. *Management Need:* Use genetic data to improve our understanding of the distribution of spring and summer run Chinook Salmon juveniles and thus improve our ability to prioritize restoration projects targeting spring Chinook Salmon recovery. *Partners:* USFWS Mid-Columbia FWCO

Design and installation of a PIT tag array to monitor outmigration of juvenile Pacific lamprey in the Umatilla River. *Management need:* Determine entrainment rates of juvenile lamprey as they move downstream through the Umatilla River. *Partners:* NOAA-Fisheries, US Bureau of Reclamation

Rapid response genetic analysis of threatened bull trout collected below dams in the Clark Fork River, MT. *Management Need:* Provide data to inform upstream fish passage decisions for listed bull trout. *Partners:* Avista Corporation; Confederated Salish Kootenai Tribes; Idaho Fish and Game; Kalispel Tribe of Indians; Montana Fish Wildlife & Parks; Montana Ecological Services Field Office; Pend Oreille Public Utility District; Pennsylvania Power & Light, MT.

Genetic identification of endangered winter-run Chinook salmon in the Sacramento River, CA. *Management Need:* Rapid response broodstock identificaonfor spawning of listed species. *Partners:* Livingston Stone NFH; Red Bluff FWO; NOAA Fisheries.

Genetic analysis of bull trout in the Lewis River system. *Management Need:* Facilitate passage of bull trout past hydroelectric facilities. *Partners:* Washington FWO, Columbia River FPO, PacifiCorp, US Forest Service, Washington Department of Fish and Wildlife.

Relative reproductive success of hatchery and wild steelhead in the Deschutes River basin. *Management Need:* Develop genetic markers to monitor genetic diversity of listed populations. *Partners:* Oregon Department of Fish and Wildlife, Idaho Department of Fish and Game, Columbia River Intertribal Fish Commission.

Genetic needs assessment for endangered Lost River and short nose suckers of the Klamath River Basin, OR. *Management Need:* Develop genetic markers to monitor genetic diversity of listed populations. *Partners:* Klamath Falls FWO; U.S. Geological Survey.

Genetic profiles of broodstock at Pacific Region National Fish Hatcheries. *Management Need:* Determine impacts of hatchery origin fish (HOR) on naturally occurring fish (NOR) and monitor the effects of aquaculture practices on HOR populations. *Partners:* Pacific Region NFHs; Fishery Resources Program via FONS.

Genetic run assignment of juvenile Chinook salmon from the American River. *Management Need:* Assess accuracy of length-at-date method for distinguishing Spring run (ESA listed) from Fall run (unlisted) Chinook salmon smolts. *Partner:* Pacific Southwest Regional Office.

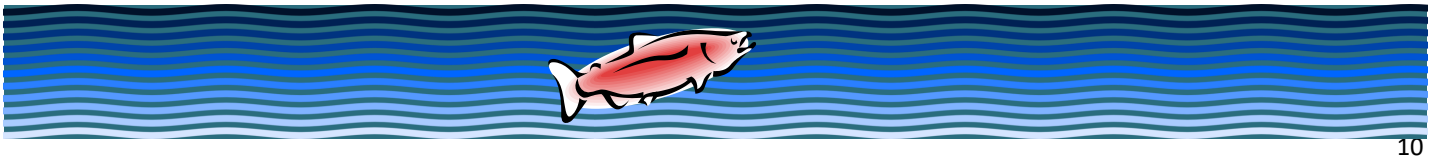
Bull trout SNP marker discovery using RAD-seq. Management need: Identify a standardized panel of SNP genetic markers that can be applied to population genetics studies across the species' range. Partners: Washington Department of Fish and Wildlife, Columbia River Inter-Tribal Fish Commission.

Evaluating population structure and effective population size of redband trout in the Deschutes River, OR. Management need: Genetic data will help identify management units for redband trout in the Deschutes River basin. Partners: Oregon Department of Fish and Wildlife.

Genetic assessment of bull trout in the Upper Willamette River, OR. Management need: Provides genetic information relevant to assessing the conservation status of the species and fish passage. Partners: Oregon Department of Fish and Wildlife.

Use of Genetic Analysis to Determine Origins of Prickly Sculpin Populations in Nisqually River Basin. Management Need: Evaluate the use of genetic tools to identify origin of an introduced population. Partner: Western Washington FWCO.

Population structure of coastal cutthroat trout inhabiting urban watersheds in Portland, OR. Management Need: Compare the characteristics of urban populations with their non-urban counterparts. Partner: Columbia River FWCO.



Publications

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Barron, J. M., **Twibell**, R. G., Hill, H. A., **Hanson**, K. C. & **Gannam**, A. L. 2016. Development of diets for the intensive culture of Pacific lamprey. Aquaculture Research 47: 3899-3906.

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